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Comparison of Texel- and Suffolk-Sired Crossbred Lambs for Survival, Growth, and Compositional Traits

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ABSTRACT: Texel sheep were imported from Finland and Denmark for evaluation as a terminal sire population relative to the Suffolk breed. The objective was to estimate effects of sire breed on fitness, growth, and compositional traits of crossbred progeny that were serially slaughtered at 63, 105, 147, and 189 d of age. A total of 325 lambs, sired by 19 Texel and 20 Suffolk rams, were born to mature, half-Finnsheep ewes during a 2-yr period. Carcass traits were recorded on 183 lambs. Texel-sired lambs had greater survival to weaning ($P = .06$) and similar birth and weaning weights compared with Suffolk progeny. Lambs by Texel sires grew 11% less rapidly from 63 to 189 d of age. Estimated accretion rates of carcass fat at 189 d of age were 96.1 and 78.5 g/d for Suffolk and Texel progeny, respectively. Corresponding values for carcass protein were 17.4 and 16.0 g/d. At fixed ages, area of the longissimus muscle did not differ between sire breeds. Texel progeny weighed less at 189 d of age, producing lighter, leaner carcasses of shorter length ($P < .05$). Compositional differences were not detected when sire breeds were compared at 25 kg of carcass weight. However, Texel progeny had significantly greater depth of fat at the 12th rib and weight of kidney-pelvic fat. Data indicated that Texel-sired lambs deposited proportionally more subcutaneous and less intermuscular fat than did lambs by Suffolk sires. Due to the apparent advantage in lamb survival and the observation that Texel progeny produce lean carcasses relative to the intermediate growth rate and mature size characteristic of the breed, it is concluded that Texel sheep can be used effectively as a terminal sire breed.

Key Words: Sheep, Suffolk, Texel, Growth Traits, Carcass Composition, Lamb Survival

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Introduction

Terminal sire breeds of sheep should produce at optimal levels of performance for fertility of purebred rams and for survival, lean growth rate, feed intake, and carcass composition of crossbred progeny. Lean growth rate is emphasized in the United States, where the Suffolk breed is the dominant terminal sire breed. However, other breeds throughout the world may be competitive with the Suffolk. Global screening of breeds followed by importation and experimental evaluation of the most promising breeds is an effective strategy to exploit genetic resources. European experiments that evaluated numerous terminal sire breeds indicated that crossbred progeny of Texel rams were intermediate for postweaning growth rate but excelled in carcass traits such as leanness, lean:bone ratio, and area of the longissimus muscle (More O'Ferrall and Timon, 1977a,b; Wolf et al., 1980; Cameron and Drury, 1985; Croston et al., 1987; Kempster et al., 1987). Based on the European results, it seemed fitting to import and evaluate the Texel breed as an alternative terminal sire breed to the Suffolk. The experimental objective was to estimate effects of Texel and Suffolk rams on fitness, growth, and compositional traits of crossbred progeny that were serially slaughtered at 63, 105, 147, and 189 d of age.

Materials and Methods

General Information

Data were collected on 325 lambs born during 1988 and 1989 at the Roman L. Hruska U.S. Meat Animal Research Center (MARC). In compliance with importation requirements, the experiment was conducted within a quarantine facility established at MARC. Lambs were born to Composite I ewes (Fogarty et al., 1984a,b) derived from 50% Finnsheep, 25% Dorset, and 25% Rambouillet germ plasm. To maximize lamb

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production per ewe and to minimize effects associated with age of dam, only mature ewes (3 through 6 yr of age) were included in the experiment. The ewes were single-sire-mated to Suffolk or Texel rams and different rams were used each year.

Sampling of Sire Breeds

Registered Texel sheep were imported from Finland and Denmark during 1985. Although the opportunity to select among sheep available for importation was quite limited, genetic diversity and growth rate were emphasized. Twenty pregnant Texel ewes, which had been mated by five Texel rams, were sampled from one flock in Finland. Four of the five rams mated to the 20 ewes were also imported. Five Texel rams were imported from Denmark, each ram sampled from a different flock. One of the Danish Texel rams died before mating any ewes at MARC. The four remaining rams of Danish origin were mated to the Texel ewe flock during 1985, 1986, and 1987. For evaluation purposes, Composite I ewes were mated to nine Texel rams in 1987 and to 10 different Texel rams in 1988. The rams used in 1987 were seven imported rams and two sons of imported rams, whereas only sons of original sires were used in 1988. When the experiment started, the Texel sheep at MARC were the only source of Texels in North America.

Twenty Suffolk rams were mated to Composite I ewes, 10 rams in each year. We attempted to sample the Suffolk breed so that inferences would apply to Suffolk flocks providing rams to the commercial industry (Hill, 1979). The majority of rams were purchased at central test sales and purchased rams were subjectively appraised as having greater muscle mass than contemporary rams. The remaining rams were chosen in a like manner from the genetically diverse Suffolk flock at MARC (Leymaster, 1991).

Experimental Procedure

To reduce variation in lambing date, ewes were synchronized during early November of each year. The Suffolk and Texel rams were each joined with four or five mature Composite I ewes. The ewes grazed pasture throughout gestation with supplemental feed provided to maintain sufficient body condition. Lambing occurred in drylot with ranges in lambing dates of 11 d in 1988 and 10 d in 1989. A total of 325 lambs were born in 124 litters, averaging 2.6 lambs per litter. Shortly after birth, lambing difficulty and vigor scores were assigned to each lamb. Ewes judged capable of rearing three lambs were allowed to do so; however, approximately 21% of lambs were reared artificially. Naturally reared lambs of both sire breeds and all ewes, regardless of number reared, were managed together in a single group. A pelleted, alfalfa-corn diet containing 14.5% CP and 2.95 Mcal/kg of dietary DM was provided to lambs by 14 d of age, and all male lambs were castrated at approximately 25 d of age. Weaning occurred on a single day each year when lambs averaged 51 d of age (SD of 3.0 d). Survival (0, 1) to weaning was recorded for each of the 325 lambs born. Weaning weights of 215 naturally reared lambs were adjusted to a constant age of 51 d by use of individual preweaning daily gains. Weaning weight and preweaning daily gain data of 61 artificially reared lambs were not analyzed, because we wanted estimates of sire breed effects on postnatal growth to have inference to lambs reared by their own dam.

Postweaning growth and carcass data were collected only on multiple-born, multiple-reared lambs to experimentally, rather than statistically, account for effects of type of birth and rearing. This constraint excluded 93 (34%) of the 276 weaned lambs, leaving 183 ewe and wether lambs for slaughter. Four slaughter dates were determined each year, corresponding to average ages of 63, 105, 147, and 189 d. Approximately one-fourth of the lambs were slaughtered at each intended age. Lambs were identified for slaughter within sex, sire-breed groups. Within group, a selected sample was determined so the sample mean for live weight was similar to the group mean. All lambs were slaughtered at the MARC abattoir.

Carcass Evaluation

Traits recorded at slaughter were age, unshrunk live weight, and weights of pelt (including feet), liver, carcass, and kidney-pelvic fat. The warm carcass weight included kidney-pelvic fat. The day after slaughter, chilled carcasses were graded for quality, leg conformation, and muscling (USDA, 1969). Subcutaneous fat depth was recorded at two locations, three-fourths the lateral distance over the longissimus muscle at the 12th rib and at the midline of the fourth sacral vertebra. The area of the longissimus muscle between the 12th and 13th ribs and carcass length from the anterior edge of the first rib to the anterior edge of the aitchbone were recorded.

The entire carcass, bone included, of each lamb slaughtered at 63 or 105 d of age and one side of the carcass from each lamb slaughtered at 147 or 189 d of age were ground for chemical analyses. A single sample of approximately 100 g was collected from each carcass for determination of water, fat (ether extract), protein ($N \times 6.25$), and ash, calculated as constituents of the complete warm carcass (AOAC, 1970).

The remaining carcass sides of the 94 lambs slaughtered at 147 and 189 d of age were divided into seven primal cuts (neck, shoulder, rib, fore shank and breast, loin and flank, leg and hind shank, and sirloin) using anatomical reference points. Subcutaneous fat was separated from each cut and the shoulder was further dissected into intermuscular fat, lean, and bone, including waste. The dissection data were collected to investigate the distribution of fat among kidney-pelvic, subcutaneous, and intermuscular depots.

Statistical Procedures

Data were analyzed using least squares mixed-model procedures (Harvey, 1985). All traits were defined on an individual lamb basis with the exception of number born, which was expressed per ewe lambing. The model for number born fit effects of combinations (**YB**) of year of lamb birth (**Y**; 1988, 1989) with sire breed (**B**; Suffolk, Texel) and sires of lambs within YB.

Traits recorded to weaning were analyzed by fitting effects of YB, sires within YB, sex (**S**; female, male), S × YB, and the linear and quadratic pooled regressions on type of birth. Type of birth (number born) ranged from one to five lambs and averaged 2.88 for all lambs born, compared with 2.71 for naturally reared, weaned lambs. Least squares means of effects on birth weight and survival percentage have inference to the value of 2.88, whereas least squares means of effects on preweaning daily gain and weaning weight relate to the value of 2.71.

Although postweaning data were collected only on multiple-born, multiple-reared lambs, preliminary analyses of postweaning traits were conducted to investigate potential effects of type of birth, type of rearing, and the interaction of sex with slaughter age. To accommodate this objective, type of birth and type of rearing were fit as discrete effects, rather than continuous, so that constant estimates could be examined. Type of birth (2, 3, 4, or 5) was statistically significant for 3 of 15 traits analyzed. The effect of type of rearing (2 or 3) did not approach statistical significance for any trait. The quadratic regression coefficients on slaughter age did not differ significantly between sexes for any trait and were deleted from the model. The remaining linear regression coefficients differed significantly between sexes for a single trait. For the sake of consistency among postweaning traits, a common model was chosen and the effects of type of birth, type of rearing, and the interaction of sex with slaughter age were not considered further.

The final model for traits recorded at slaughter fit effects of YB, sires within YB, S, S × YB, and linear and quadratic regressions on slaughter age, specific to each class of YB. This model was used to characterize developmental growth of Texel- and Suffolk-sired lambs, the primary objective of the experiment. Additionally, effects of sire breeds were estimated at each intended slaughter age (63, 105, 147, or 189 d) as detailed by Harvey (1985).

For each trait, the YB sum of squares was partitioned into variation due to Y, B, and Y × B interaction effects using linear contrasts of the YB constant estimates. The resulting mean squares of Y, B, and Y × B were tested against the mean square of sires within YB. Levels of significance associated with the effects of Y, B, and Y × B are approximations due to the unbalanced nature of the data. The least squares mean of each sire breed was estimated as a linear function of constant estimates of μ and YB effects. In a similar manner, the sum of squares due to the S × YB interaction was completely decomposed into two- and three-way interactions (S × Y, S × B, and S × Y × B). Likewise, the sum of squares due to deviations of the YB quadratic regression coefficients from the average quadratic coefficient was partitioned into effects due to Y, B, and Y × B. Tests of significance for traits not normally distributed are not exact and should be interpreted with caution.

Breed of sire effects on fat distribution were evaluated by analyzing kidney-pelvic and subcutaneous fat weights adjusted by slaughter age to a common average weight of total carcass fat. The adjustments used regressions of all three fat traits on slaughter age, an experimentally controlled environmental factor, rather than regressions of component traits on carcass fat, a response variable. First, carcass fat was analyzed by fitting effects of YB, sires within YB, S, S × YB, and linear regressions on slaughter age, specific to each class of YB. The estimate of μ for carcass fat at the covariate value of 168 d (the mean of the intended slaughter ages, 147 and 189 d) was 7.2 kg. Then the slaughter ages at which Texel- and Suffolk-sired progeny had 7.2 kg of carcass fat were derived based on the breed-specific regression equations generated by analysis of carcass fat. Values of 175.8 and 160.9 d were calculated for lambs by Texel and Suffolk sires, respectively. Finally, kidney-pelvic fat and subcutaneous fat (expressed on a whole-carcass basis) were analyzed using the same model as carcass fat, but varying the mean of slaughter age (i.e., least squares means of Texel progeny for kidney-pelvic fat and subcutaneous fat were estimated at a slaughter age of 175.8 d, whereas least squares means of Suffolk-sired lambs were determined at 160.9 d). Similarly, shoulder intermuscular fat was analyzed at slaughter ages of 172.5 d for Texel progeny and 164.5 d for lambs by Suffolk sires, these ages corresponding to the production of .328 kg of shoulder subcutaneous fat. Standard errors of constant estimates were used in *t*-tests to determine the significance of sire breed effects on the distribution of fat depots.

Results

Analyses of traits recorded to weaning revealed that no interactions involving sire breed were statistically significant for any trait. Consequently, least squares means are tabulated only for the main effect of sire breed. Although the pooled quadratic regression coefficient of each trait on type of birth at least approaches significance ($P < .10$), these estimates and the main effect of sex and its interaction with year are

Table 1. Summary of analyses of covariance of traits measured to weaning

Item	No. born	Birth wt, kg	Survival percentage	Daily gain, g	Weaning wt, kg
Least squares means			†		
Texel	2.63	3.52	86	219	14.9
Suffolk	2.61	3.53	77	224	15.3
Avg SEM	.13	.087	3.7	8.0	.45
Significance of sires/year-breed	**	**	†	**	**
Residual SD	.74	.65	35	52	3.0

†$P < .10$.
**$P < .01$.

considered impertinent to the primary experimental objective and are neither tabulated nor discussed.

Texel and Suffolk sires had similar effects on the number of lambs born per ewe lambing and on birth weight of individual lambs (Table 1). However, Texel progeny had 9% greater survival to weaning ($P = .06$). The effect of sire breed on survival percentage was not likely associated with lambing difficulty because < 5% of lambs required assistance at birth. Rather, the difference between sire breeds for preweaning survival was largely due to fewer Texel progeny found dead at birth. Naturally reared lambs by Texel and Suffolk rams had similar values for preweaning daily gain and for weaning weight. Significant variation among sires for each trait provided evidence of direct additive effects within sire breeds.

Effects of sire breed did not interact significantly with other discrete sources of variation for any trait measured after weaning. Coefficients of second-order regression equations are presented by sire breed for each trait in Table 2. The coefficients are coded relative to actual days of age rather than deviations from the average age as calculated by Harvey (1985). The average quadratic coefficient from regression of slaughter, carcass, and compositional traits on slaughter age was statistically significant for each trait except carcass weight, fat depths at the 12th rib and fourth sacral vertebra, longissimus muscle area, and percentage of fat ($P > .10$). These latter traits increased linearly as slaughter age increased (i.e., rates of change were constant). In contrast, rates of change decreased as slaughter age increased for all the remaining traits except kidney-pelvic fat and carcass fat, which cumulated at greater rates with advanced age. The Texel and Suffolk quadratic coefficients differed significantly only for the regressions of subjectively appraised traits (muscling and leg conformation scores) on slaughter age.

Table 2. Regression equations of response variables on days of age by sire breed

Trait	Texel			Suffolk		
	Intercept	Linear	Quadratic	Intercept	Linear	Quadratic
Live wt, kg	−2.740	.35736	−.000396	−5.180	.39972	−.000451
Pelt wt, kg	−.716	.04293	−.000030	−1.385	.05364	−.000069
Liver wt, kg	−.134	.00819	−.000014	−.252	.01099	−.000025
Carcass wt, kg	−1.005	.15048	−.000019	−1.816	.15731	.000032
Kidney-pelvic fat wt, kg	.310	−.00629	.000056	.065	−.00336	.000049
Fat depth, cm						
12th rib	−.365	.00680	−.000006	−.333	.00506	.000001
Fourth sacral vertebra	−.664	.01254	.000008	−.681	.01062	.000020
Carcass length, cm	30.094	.27423	−.000602	31.322	.28706	−.000619
Longissimus muscle area, cm^2	4.793	.06368	−.000019	2.701	.09231	−.000121
Carcass						
Ash, kg	−.043	.00724	−.000007	−.113	.00868	−.000010
Fat, kg	.043	.00778	.000187	−.488	.00949	.000229
Protein, kg	−.305	.02843	−.000033	−.353	.02946	−.000032
Water, kg	−.601	.10458	−.000156	−.790	.10757	−.000146
Percentage of fat	5.624	.12898	.000017	4.198	.14594	.000019
Percentage of protein	16.614	−.00034	−.000056	17.096	−.00575	−.000054
Carcass scores[a]						
Quality	−4.287	.18810	−.000564	−5.102	.19787	−.000581
Leg conformation	1.093	.14487	−.000451	4.790	.08420	−.000250
Muscling	2.472	.12698	−.000400	6.170	.05586	−.000136

[a]Carcasses graded average Utility, average Good, average Choice, or average Prime have values of 5, 8, 11, or 14, respectively.

Table 3. Summary of analyses of covariance of slaughter and carcass traits adjusted to fixed ages

Item	Live wt, kg	Pelt wt, kg	Liver wt, kg	Carcass wt, kg	Kidney-pelvic fat wt, kg	Fat depth, cm		Carcass length, cm	LM[b] area, cm^2
						12th rib	FSV[a]		
63 d								*	
Texel[c]	18.2	1.87	.326	8.4	.14	.04	.16	45.0	8.7
Suffolk[c]	18.2	1.72	.341	8.2	.05	−.01	.07	46.9	8.0
Avg SEM	1.26	.20	.030	.71	.048	.034	.091	.66	.48
105 d			†			*		**	
Texel[c]	30.4	3.46	.571	14.6	.27	.28	.74	52.3	11.3
Suffolk[c]	31.8	3.49	.626	15.1	.26	.21	.65	54.6	11.1
Avg SEM	.91	.15	.022	.52	.035	.024	.066	.48	.34
147 d	†		†	†		*		***	
Texel[c]	41.2	4.95	.767	20.7	.60	.50	1.35	57.4	13.7
Suffolk[c]	43.8	5.01	.823	22.0	.63	.43	1.31	60.1	13.7
Avg SEM	.93	.15	.022	.53	.036	.025	.067	.49	.35
189 d	*			*				***	
Texel[c]	50.7	6.33	.913	26.8	1.12	.71	1.99	60.4	16.2
Suffolk[c]	54.3	6.29	.931	29.1	1.18	.66	2.04	63.5	15.8
Avg SEM	1.13	.18	.027	.64	.043	.030	.082	.60	.43
Significance of sires/ year-breed	**	**	**	**	—	—	—	***	*
Residual SD	4.2	.66	.10	2.5	.20	.18	.38	2.0	1.7

[a]Fourth sacral vertebra.
[b]Longissimus muscle.
[c]Least squares means.
†$P < .10$.
*$P < .05$.
**$P < .01$.
***$P < .001$.

The regression equations were used to estimate effects of sire breeds on slaughter and carcass traits at the intended slaughter ages of 63, 105, 147, and 189 d (Table 3). Texel and Suffolk progeny were similar for 63-d weight, but thereafter Texel-sired lambs averaged 11% less rapid growth than did lambs by Suffolk sires. Consequently, Suffolk progeny were 7% heavier ($P < .05$) at 189 d of age. Differences between sire breeds for pelt weight were not detected at any age, whereas Suffolk-sired lambs had heavier livers than Texel progeny at the intermediate ages ($P < .10$). Effects of sire breed on carcass weight followed the same pattern as live weight: lambs by Suffolk sires produced carcasses that were 9% heavier at 189 d of age than carcasses of Texel progeny ($P < .05$). At each age, progeny of Texel and Suffolk sires did not differ significantly for weight of kidney-pelvic fat or depth of fat at the fourth sacral vertebra. However, Texel-sired lambs consistently had greater fat depth at the 12th rib and breed differences were detected at 105 and 147 d of age ($P < .05$). Carcasses of Suffolk-sired lambs were longer at 63 d of age ($P < .05$) and the difference increased to approximately 3 cm (5%) at 189 d of age ($P < .001$). Effects of sire breed on area of the longissimus muscle were not significant at any age.

Effects of Suffolk and Texel sires on carcass ash, fat, protein, and water were also estimated at the four intended slaughter ages (Table 4). Texel and Suffolk progeny had similar weights of each carcass constituent at 63 d of age, but thereafter lambs by Suffolk sires had greater weights of each constituent. By 189 d of age, Suffolk-sired lambs yielded 8 ($P < .05$), 16 ($P < .01$), 5 ($P > .10$), and 5% ($P > .10$) more weight of carcass ash, fat, protein, and water, respectively, than Texel progeny.

Because accretion rates of carcass fat and protein are important traits affecting lean growth efficiency, the experiment was specifically designed to allow estimation of these key characteristics over a wide range of ages. This was accomplished by taking first derivatives of the appropriate regression equations presented in Table 2; the results are illustrated in Figure 1. During the 126-d interval, the accretion rate of carcass fat increased daily by .458 g for Suffolk-sired lambs compared with .374 g for Texel progeny, a difference of approximately 22%. Consequently, the estimated accretion rates of carcass fat at 189 d of age were 96.1 and 78.5 g/d for Suffolk and Texel offspring, respectively. In contrast, the accretion rate of carcass protein decreased as lambs became older and the rate of decrease was similar between sire breeds (Suffolk, −.064 g/d; Texel, −.066 g/d). Lambs by Suffolk sires were depositing protein 9% more rapidly than Texel progeny at 189 d of age (17.4 vs 16.0 g/d).

The accretion rates of carcass fat and protein illustrated in Figure 1 are presented relative to one another in Figure 2. Texel-sired lambs always are older than Suffolk progeny compared at the same ratio of fat:protein accretion rates. Stated differently, Suffolk-sired lambs deposit relatively more fat than

Table 4. Summary of analyses of covariance of compositional traits and of carcass scores adjusted to fixed ages

Item	Carcass, kg Ash	Carcass, kg Fat	Carcass, kg Protein	Carcass, kg Water	Percentage of fat	Percentage of protein	Quality[a]	Leg conformation[a]	Muscling[a]
63 d									
Texel[b]	.39	1.28	1.35	5.37	13.8	16.37	5.32	8.43	8.88
Suffolk[b]	.39	1.02	1.38	5.41	13.5	16.52	5.06	9.10	9.15
Avg SEM	.032	.29	.096	.35	.72	.15	.28	.36	.32
105 d									*
Texel[b]	.64	2.92	2.32	8.66	19.4	15.96	9.25	11.33	11.39
Suffolk[b]	.69	3.03	2.39	8.90	19.7	15.90	9.27	10.87	10.54
Avg SEM	.023	.21	.069	.25	.52	.11	.20	.26	.23
147 d	*	*				†		*	**
Texel[b]	.87	5.23	3.16	11.40	25.0	15.35	11.17	12.64	12.49
Suffolk[b]	.95	5.86	3.29	11.87	26.1	15.08	11.43	11.77	11.44
Avg SEM	.024	.21	.071	.25	.53	.11	.20	.26	.24
189 d	*	**			†	*			
Texel[b]	1.08	8.19	3.89	13.59	30.6	14.55	11.12	12.36	12.18
Suffolk[b]	1.17	9.49	4.07	14.33	32.5	14.08	11.54	11.77	11.87
Avg SEM	.029	.26	.086	.31	.65	.14	.25	.32	.29
Significance of sires/year-breed	**	†	**	**	†	—	—	*	—
Residual SD	.11	1.1	.32	1.1	2.8	.65	1.1	1.3	1.4

[a]Carcasses graded average Utility, average Good, average Choice, or average Prime had values of 5, 8, 11, or 14, respectively.
[b]Least squares means.
†$P < .10$.
*$P < .05$.
**$P < .01$.

protein compared with Texel progeny at any age and the discrepancy increases with age. Suffolk-sired lambs deposit fat 5.5 times more rapidly than protein by 189 d of age, compared with a value of 4.9 for lambs by Texel sires.

The ratio of fat:protein accretion rates is useful to interpret changes in carcass composition associated with age (Table 4): composition at a given age expresses the cumulative effects of differential accretion rates of constituents to that age. Although Suffolk and Texel progeny are similar for both percentage of fat and percentage of protein at 63 d of age, Texel-sired lambs have less percentage of fat ($P < .10$) and greater percentage of protein ($P < .05$) than Suffolk offspring at the final age.

Quality grades of sheep carcasses are based on the assessed palatability of lean tissue and the conformation of the carcass. Progeny of Suffolk and Texel rams

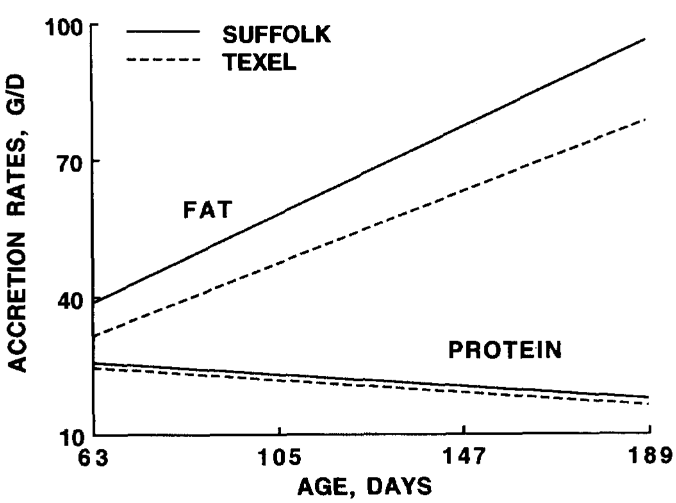

Figure 1. Accretion rates of carcass fat and protein as Texel- and Suffolk-sired crossbred lambs grew from 63 to 189 d of age.

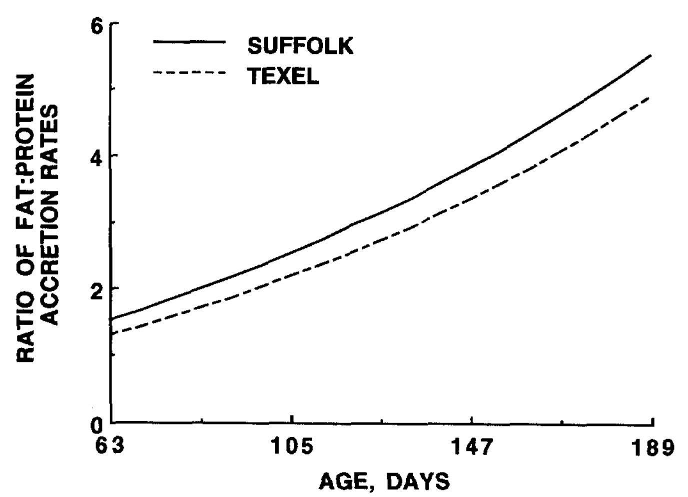

Figure 2. Ratio of fat:protein accretion rates as Texel- and Suffolk-sired crossbred lambs grew from 63 to 189 d of age.

Table 5. Summary of analyses of covariance of fat depots adjusted by age to fixed carcass or shoulder subcutaneous fat

	Carcass fat[a]		Shoulder s.c. fat[b]
Item	Kidney-pelvic fat wt, kg	Subcutaneous fat wt, kg	Intermuscular fat wt, kg
Least squares means			
Texel	.94	3.95	.228
Suffolk	.83	3.77	.246
Avg SEM	.050	.16	.011
Significance of sires/year-breed	*	—	—
Residual SD	.24	1.0	.063

[a]The derived ages when Texel- and Suffolk-sired progeny had 7.2 kg of carcass fat were 175.8 and 160.9 d, respectively.
[b]The derived ages when Texel- and Suffolk-sired progeny had .328 kg of shoulder subcutaneous fat were 172.5 and 164.5 d, respectively.
*$P < .05$.

did not differ significantly at any age for quality grades (Table 4). However, Texel rams produced lambs with significantly greater leg conformation and carcass muscling scores at the intermediate ages, indicating greater thickness and plumpness relative to length. These results are consistent with estimated breed effects on carcass length and longissimus muscle area, objectively measured traits reported in Table 3. Despite lighter weight and shorter length, carcasses of Texel-sired lambs had longissimus muscle areas that were at least as great as carcasses of lambs by Suffolk sires.

Compared at 7.2 kg of total carcass fat, Texel offspring had 13% more kidney-pelvic fat and 5% more subcutaneous fat than Suffolk-sired lambs, although the effects of sire breed were not statistically significant based on limited dissection data (Table 5). Nonetheless, the above results imply less inter- and(or) intramuscular fat for lambs by Texel sires. This notion is supported by estimates of breed effects on weight of shoulder intermuscular fat when compared at a fixed weight of shoulder subcutaneous fat. Lambs by Texel sires had 7% less intermuscular fat than did Suffolk progeny ($P > .10$). The tendencies noted in the dissection data were upheld indirectly by analyses of the total data set. Suffolk-sired lambs had significantly more carcass fat than Texel offspring at 147 and 189 d of age (Table 4) but similar weight of kidney-pelvic fat and less depth of fat at the 12th rib (Table 3). Taken together, these results suggest that Suffolk and Texel inheritance has different effects on the distribution of fat depots.

Besides the age-constant estimates reported in Tables 3 and 4, other comparative biological and(or) economical end points were considered. The ages at which progeny of each sire breed averaged specific values for carcass weight (25 kg), 12th rib fat depth (.635 cm), percentage of fat (25%), weight of fat-free lean (approximated as the sum of protein and water, 17 kg), or the ratio of fat:protein accretion rates (4) were derived from the appropriate regression equations presented in Table 2. Data were then repeatedly analyzed, setting the mean of the slaughter age covariate to the various derived ages so that least squares means of sire breeds for the remaining traits were estimated when the chosen end points were achieved (Table 6).

Because age-constant effects of sire breeds on many traits are associated with differences between breeds in weight, breed effects are also estimated independent of carcass weight. On average, Texel progeny required approximately 12 more days than Suffolk-sired lambs to produce 25 kg of carcass weight. Live weights were similar between sire breeds, but Texel offspring had heavier pelts ($P < .10$), suggesting less combined weight of organs and fill. Carcasses of Suffolk-sired lambs were longer ($P < .01$), whereas lambs by Texel sires had approximately 6% greater area of the longissimus muscle ($P < .10$). Texel progeny had significantly greater depths of fat at the 12th rib and fourth sacral vertebra, as well as weight of kidney-pelvic fat. Despite differences at specific fat depots, Texel and Suffolk progeny had virtually the same weight of carcass fat. These findings confirm that Texel and Suffolk rams have different effects on fat distribution in crossbred progeny. Values of the remaining carcass constituents also did not differ between sire breeds. It, therefore, seems that compositional differences between sire breeds at fixed ages are simply due to the heavier carcasses of Suffolk progeny relative to lambs by Texel sires (Tables 3 and 4).

Texel and Suffolk progeny were further compared at .635 cm of 12th rib fat depth due to the prominent effects of sire breed at this location and its relevance to new standards for USDA yield grades (Federal Register, 1992). The value of .635 cm represents the maximum acceptable fat depth within the yield grade 2 category, whereas carcasses graded 1 or 2 qualify for the Certified Fresh American Lamb program developed by the American Sheep Industry Association. Texel-sired lambs are approximately 11 d younger than Suffolk offspring when .635 cm of fat is

Table 6. Least squares means of sire breeds at fixed values of carcass weight (25 kg), 12th rib fat depth (.635 cm), percentage of fat (25%), weight of fat-free lean (17 kg), or ratio of fat:protein accretion rates (4)

	Carcass wt			12th rib fat depth			Percentage of fat			Fat-free lean			Fat:protein accretion rates		
Item	Texel		Suffolk	Texel		Suffolk	Texel		Suffolk	Texel		Suffolk	Texel		Suffolk
Estimated age, d	176.8		164.9	173.8		184.5	147.4		140.0	181.4		169.9	166.1		151.8
Live wt, kg	48.1		48.5	47.4	***	53.2	41.3		41.9	49.1		49.7	45.7		45.1
Pelt wt, kg	5.94	†	5.58	5.84		6.16	4.96		4.77	6.08	†	5.74	5.59	*	5.17
Liver wt, kg	.875		.880	.866	†	.924	.768		.796	.890		.893	.839		.840
Carcass wt, kg	25.0		25.0	24.6	***	28.3	20.8		20.8	25.7		25.8	23.5		22.8
Kidney-pelvic fat wt, kg	.95	*	.84	.91	***	1.11	.60		.56	1.01	*	.91	.81	*	.68
Fat depth, cm															
12th rib	.65	***	.53	.635		.635	.51	**	.40	.67	**	.56	.60	***	.46
Fourth sacral vertebra	1.80	*	1.61	1.76	*	1.96	1.36		1.20	1.87	†	1.70	1.64	**	1.39
Carcass length, cm	59.8	**	61.8	59.6	***	63.2	57.4	**	59.4	60.0	**	62.2	59.0	*	60.6
Longissimus muscle area, cm^2	15.5	†	14.6	15.3		15.6	13.8		13.3	15.7	†	14.9	14.8	†	13.9
Carcass ash, kg	1.02		1.05	1.00	***	1.15	.87		.91	1.04		1.07	.97		.97
Carcass fat, kg	7.26		7.30	7.04	***	9.06	5.25		5.33	7.61		7.74	6.49		6.23
Carcass protein, kg	3.69		3.63	3.64	**	3.99	3.17		3.14	3.77		3.73	3.51		3.38
Carcass water, kg	13.01		12.98	12.86	**	14.09	11.43		11.41	13.24		13.27	12.47		12.18
Fat-free lean, kg	16.70		16.61	16.50	**	18.08	14.59		14.55	17.00		17.00	15.97		15.56
Percentage of fat	29.0		28.8	28.6	***	31.8	25.0		25.0	29.6		29.5	27.5		26.8
Percentage of protein	14.80		14.68	14.86	***	14.20	15.35		15.23	14.7		14.6	15.01		14.98

† $P < .10$.
*$P < .05$.
**$P < .01$.
***$P < .001$.

cumulated. At this potentially critical end point, sire breeds differ significantly for all traits studied except pelt weight and area of the longissimus muscle (Table 6). The general effects of sire breed seem to be manifested primarily through weight discrepancies; Suffolk progeny produce 12% more live weight and 15% more carcass weight than lambs by Texel sires. Compositional advantages were detected for the lighter Texel progeny that had 28.6% fat compared with 31.8% fat for Suffolk-sired lambs ($P < .001$).

Because Suffolk and Texel rams affect fat distribution in crossbred progeny, resulting in meaningful compositional variation based on the yield grade criterion, an alternative marketing strategy is to slaughter lambs to achieve compositional targets. As an example, a value of 25% carcass fat was chosen for comparative purposes (Table 6). The more slowly growing Texel progeny needed approximately seven more days to reach the compositional end point than did Suffolk-sired lambs. Evaluation at 25% carcass fat reduced the number of significant differences between sire breeds relative to other comparative end points considered; effects of sire breed were only detected for 12th rib fat depth and carcass length.

Given that palatability is acceptable, one could argue that the intrinsic value of a carcass is determined solely by the weight of lean tissue or perhaps fat-free lean tissue. Implicit in this argument is the assumption that fat has no value (i.e., the cost to remove fat is equal to the salvage value). Based on this premise, breed effects were estimated independent of the weight of fat-free lean tissue, approximated by the sum of protein and water. Texel progeny are approximately 11.5 d older than Suffolk-sired lambs when 17.0 kg of fat-free lean tissue is produced. Effects of sire breed are similar to results shown for carcass weight because least squares means of sire breeds for fat-free lean do not differ when carcass weight is taken as the comparative end point (Table 6).

As a final comparative end point, the ratio of fat: protein accretion rates was used to evaluate sire breeds at the same stage of developmental maturity. Progeny of Texel and Suffolk rams are compared when the accretion rate of fat is fourfold greater than the accretion rate of protein. This stage of developmental maturity is reached when Texel-sired lambs are approximately 14 d older than Suffolk offspring. Significant effects of sire breed were detected for the same traits at this end point as for comparisons based on carcass weight and on weight of fat-free lean (Table 6).

Discussion

The use of mature, prolific ewes as a test flock to evaluate progeny by Texel and Suffolk rams has an important bearing on the interpretation and broader application of results. Ewes gave birth to an average of 2.6 lambs per litter, creating prenatal and postnatal maternal environments that may have restricted levels of performance for certain traits. Another factor to note is that lambs were fed a concentrate diet in drylot. It seems justified also to evaluate comprehensively these sire breeds using less prolific ewes in a more extensive, forage-based production system. Significant sire breed × dam breed interactions have been reported for growth and compositional traits (e.g., Kempster et al., 1987).

The primary differences between the Texel and Suffolk breeds as terminal sire populations can be attributed to four basic characteristics: survival, growth rate, fat distribution, and carcass shape. Frequent producer criticism of Suffolk-sired lambs for undesirable vigor and survival attributes is supported by experimental results (Bradford et al., 1960; Fahmy et al., 1972; Carter and Kirton, 1975; Smith, 1977). However, the advantage ($P < .10$) of Texel-sired lambs for survival percentage in the present study was not anticipated due to the reputation of the Texel breed for dystocia problems (Visscher and Bekedam, 1984). Because lambing difficulty was scarcely observed in this study, the high reproductive rate may have favored Texel rather than Suffolk progeny. It is important to confirm the Texel advantage for survival over a range of ewe types, conducting experiments of sufficient size to give more precise estimates than reported herein.

The Suffolk breed has greater potential for growth than does the Texel breed. Weights of mature, purebred Suffolk and Texel ewes have averaged 94.5 and 74.5 kg, respectively, in the experimental flocks at MARC. Suffolk rams produced crossbred lambs that grew 11% more rapidly from 63 to 189 d of age than Texel progeny. In terms of carcass constituents, linear estimates of accretion rates for ash, fat, protein, and water were 6.2, 67.2, 21.3, and 70.8 g/d for lambs by Suffolk sires compared with 5.5, 54.8, 20.2, and 65.2 g/d for Texel progeny. Preweaning daily gain did not differ between sire breeds ($P > .10$), perhaps suggesting that the multiple-rearing environment suppressed the growth potential of Suffolk progeny more so than Texel progeny. Despite different growth potentials, progeny of Texel and Suffolk rams did not differ significantly for compositional traits when compared at 25 kg of carcass weight. It, therefore, seems that Texel progeny produce lean carcasses relative to the intermediate growth rate and mature size characteristic of the breed (Cameron and Drury, 1985). This exception to the general interbreed relationships among growth rate, mature size, and carcass composition may provide opportunities to use Texel germ plasm in various crossbreeding roles (e.g., a contributor to a maternal composite population).

The significant effect of sire breed on fat distribution, notably at the 12th rib, is evident at every comparative end point. Results suggest that Texel progeny deposited proportionally more subcutaneous fat and less inter- and intramuscular fat than did lambs by Suffolk sires. From the standpoint of processing, it is less costly to remove subcutaneous fat than to remove intermuscular fat. Therefore, carcasses of Texel-sired lambs would seem to be more desirable because a leaner product would remain after subcutaneous fat is trimmed. However, the yield grading system will not fairly value carcasses of Suffolk- and Texel-sired lambs due to differences in fat distribution. For example, at .635 cm of 12th rib fat depth, carcasses of Texel-sired lambs weigh 3.7 kg less than carcasses of Suffolk progeny, yet the former carcasses have a smaller percentage of fat, 28.6 vs 31.8%. Lambs containing Texel germ plasm could be identified to account for this dilemma, but the long-term solution is to value carcasses based on weight of lean tissue.

It is also evident that Suffolk and Texel carcasses of equivalent weight have different shape. Texel sires produce carcasses that are more compact, being shorter in length and having larger area of the longissimus muscle. Although it is often stated that an increase in longissimus area would improve consumer acceptance of lamb, the Texel advantage of approximately 6% at 25 kg of carcass weight may not be sufficient. Regardless, the new yield grading system does not consider conformation of carcasses.

Four experiments in the United Kingdom (More O'Ferrall, 1974; More O'Ferrall and Timon, 1977a,b; Latif and Owen, 1979; Wolf et al., 1980; Croston et al., 1987; Kempster et al., 1987) and one in New Zealand (Clarke and Kirton, 1990) directly compared progeny of Texel and Suffolk rams. However, it may be fallacious to compare the present results with literature values due to differences in experimental procedures. The experiments in the United Kingdom used Texels imported from The Netherlands or France and Kempster et al. (1987) suggested that Dutch and French Texels differ in growth rate, composition, and conformation. The importation into the United States was a broad sample of the same Finnish and Danish Texels that produced embryos for importation into New Zealand. Just as Texel strains likely differ, North American Suffolks are generally considered to be larger than Suffolks found in other countries. From a nutritional aspect, the experiments in the United Kingdom and New Zealand were conducted on pasture, whereas the present study used a concentrate diet in drylot. Furthermore, slaughter end points varied considerably among experiments. Given these procedural differences, one might anticipate that estimates of sire breed effects would be inconsistent.

More O'Ferrall (1974) reported perinatal survival of 91.6 and 90.1% for Suffolk and Texel crosses, respectively. Survival to 6 wk averaged 89.6% for Suffolk progeny and 90.4% for Texel-sired lambs in the study of Latif and Owen (1979). In New Zealand, preweaning survival of Suffolk crosses was 81%, compared with 85% for Texel progeny (Clarke and Kirton, 1990). These breed effects are less than the 9% difference favoring Texel progeny in the present experiment.

It also seems that previous estimates of crossbred differences in growth are somewhat lower than those reported herein. Weights of Texel crosses relative to weights of Suffolk-sired lambs were given as 99 and 101% at 42 d (More O'Ferrall and Timon, 1977a; Latif and Owen, 1979), 94% at 84 d (Wolf et al., 1980), 97% at 98 d (More O'Ferrall and Timon, 1977a), and 96% at 140 d (Clarke and Kirton, 1990). In the present study, the predicted relative weights of Texel progeny at the same ages of 42, 84, 98, and 140 d are 98, 97, 96, and 94%, respectively.

An important discrepancy exists between previous and present results for carcass composition. The advantage of Texel offspring for percentage of lean was reported as 4.1% (More O'Ferrall and Timon, 1977b), 4.0% (Latif and Owen, 1979), 4.2% (Wolf et al., 1980), 1.9 and 1.7% (Croston et al., 1987), and 3.0% (Clarke and Kirton, 1990). Correspondingly, the differences in percentage of carcass fat of Texel-sired lambs relative to progeny of Suffolk sires were −4.7% (More O'Ferrall and Timon, 1977b), −6.2% (Latif and Owen, 1979), −3.5% (Wolf et al., 1980), −.8 and −.7% (Croston et al., 1987), and −3.8% (Clarke and Kirton, 1990). In contrast, we estimated virtually no compositional differences between sire breeds at 25 kg of carcass weight.

Wolf et al. (1980) and Croston et al. (1987) reported that the ratio of subcutaneous:intermuscular fat was greater for Texel progeny compared with Suffolk-sired lambs. Although their results were based on dissection data, our less direct evidence confirmed the distinct effects of these sire breeds on fat distribution. However, Clarke and Kirton (1990) provided evidence that seemingly disagrees with prior findings.

With regard to carcass shape, data reported by More O'Ferrall and Timon (1977a,b), Wolf et al. (1980), and Clarke and Kirton (1990) generally indicate the compact nature of carcasses produced by Texel sires; our results provide verification. Yet Kempster et al. (1987) did not detect differences in carcass conformation when French Texels were evaluated.

Given the experimental conditions and traits recorded, the Texel breed is recommended for use as a terminal sire breed. In this role, additional information is needed with regard to lambing difficulty and lamb survival. Furthermore, it is critical to estimate the relationship between feed intake and lean growth rate within the Texel and Suffolk breeds. Because the role of the Texel breed may eventually extend beyond siring market lambs, evaluation of components of reproductive fitness in crossbred and purebred ewes is also warranted. Accordingly, two long-term projects have been started at MARC to address these issues.

Implications

Texel rams can be used to sire market lambs. The differences between the Suffolk and Texel breeds as terminal sire populations are due to survival, growth rate, carcass shape, and fat distribution. Texel-sired lambs may experience less preweaning mortality and have weaning weights equal to those of lambs by Suffolk sires. Although Texel progeny grow less rapidly after weaning, carcasses of Texel- and Suffolk-sired lambs have similar composition when compared at the same carcass weight. Lambs by Texel sires have more compact carcasses and tend to deposit more of their fat on the outside of the carcass than between muscles.

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